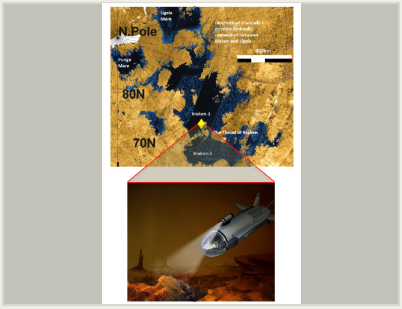
Titan Submarine: Exploring the Depths of Kraken

Completed Technology Project (2014 - 2015)

Project Introduction

Titan is unique in the outer solar system in that it is the only one of the bodies outside the Earth with liquid lakes and seas on its surface. The Titanian seas, however, are not composed of water, like Earth's seas, but are seas of liquid hydrocarbons. What lies beneath the surface of Titan's seas? We propose to develop a conceptual design of a submersible autonomous vehicle (submarine) to explore extraterrestrial seas. Specifically, to send a submarine to Titan's largest northern sea, Kraken Mare. This craft will autonomously carry out detailed scientific investigations under the surface of Kraken Mare, providing unprecedented knowledge of an extraterrestrial sea and expanding NASA's existing capabilities in planetary exploration to include in situ nautical operations. Sprawling over some 1000 km, with depths estimated at 300 m, Kraken Mare is comparable in size to the Great Lakes and represents an opportunity for an unprecedented planetary exploration mission. This mission would be a logical follow-on to a Titan surface mission such as TiME (Titan Mare Explorer) or even a component of a flagship mission of multiple vehicles. The mission concept we propose to study will investigate a full spectrum of oceanographic phenomena: chemical composition of the liquid, surface and subsurface currents, mixing and layering in the "water" column, tides, wind and waves, bathymetry, and bottom features and composition. Measurements of all these aspects of Titan's hydrocarbon ocean environment can only be made through focused in situ exploration with a well-instrumented craft. This investigation represents a significant advancement in our understanding of the history and evolution of organic compounds in the solar system, and hence a critical step along the path to understanding the evolution of life here on Earth and potential life elsewhere in the galaxy. While concepts of exploring extraterrestrial oceans, specifically Titan's, have been proposed in the past they have centered on simple suspended probes or 'diving bells' (Lorenz, 2009, Epperly et al., 2010.) Titan Submarine, or Titan Sub for short, will be a fully autonomous, highly capable science craft that will allow a complete exploration of what exists beneath the waves on another world. As such no one has yet envisioned what such a craft might look like, how it would operate or if it could be built; this is the conceptual mission design work we propose with Titan Sub. The Titan Sub addresses NASA's strategic goals 2, 3, and 6 by exploring the Titan environ-ment which could hold clues to how earth and life formed, it will create new technologies in the form of a semi-autonomous planetary submersible which could be extended to other planetary oceans, and would capture the imaginations of educators and students by sharing with them exploration of a completely new environment on a foreign world. Titan Sub will also address the NASA technology areas of Space Power and Energy Storage, Robotics and Autonomous Systems, Communications and Navigation Systems, Science Instruments and Sensors, Materials, and Thermal Management Systems. By addressing the challenges of autonomous submersible exploration in a cold outer solar system environment, Titan Sub serves as a pathfinder for even more exotic future exploration of the subsurface water oceans of Europa etc.



Concept graphic of project

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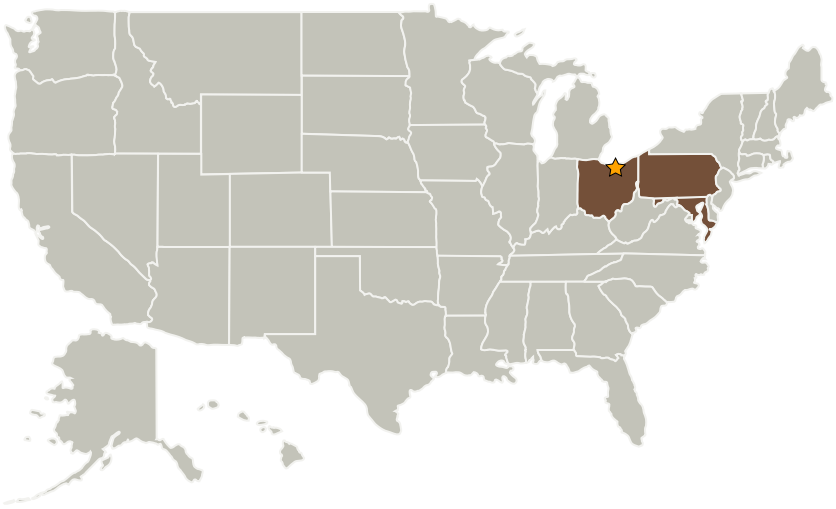
Anticipated Benefits

By addressing the challenges of autonomous submersible exploration in a cold outer solar system environment, a Titan Sub could serve as a pathfinder for even more exotic future exploration of the subsurface water oceans of Europa.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Glenn Research Center(GRC)	Lead Organization	NASA Center	Cleveland, Ohio
Johns Hopkins University Applied Physics Laboratory(JHU/APL)	Supporting Organization	R&D Center	Laurel, Maryland

Primary U.S. Work Locations	
Maryland	Ohio
Pennsylvania	

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Glenn Research Center (GRC)

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

Eric A Eberly

Principal Investigator:

Steven R Oleson

Co-Investigators:

Ralph D Lorenz
Michael S Paul

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Project Transitions

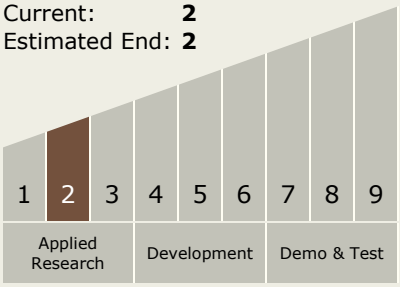
July 2014: Project Start

June 2015: Closed out

Closeout Summary: In July the Titan Submarine effort was awarded a NIAC phase II award for 2 years and $500K. The Phase II efforts will center around retiring the risks identified in phase I, refining science goals and instruments and exploring alternate submerged approaches through additional COMPASS runs. The major risks found in the Phase I conceptual design center around vehicle operations in a liquid hydrocarbon sea. Basic physics questions of operating in this cryogen need to be answered. Cryogenic experts at GRC will develop models to explore mixtures and pressures of cryogens and gases and how they would react with a warm submarine. Results from these models will be used to refine the ballast and propulsion system conceptual designs as well as feed into development of a hydrodynamic fluid models at ARL for evaluating the conceptual design. Cassini continues to observe both the constituents (remotely) and the depth of the northern Titan Seas. Up-todate data will be gathered and used as inputs for the modeling mentioned above. These data, along with the above analysis results, will be used to refine the science goals, concept of operations, and instrument suite for the Titan Sub. These activities will be led by JHU APL. The Phase II efforts will be strengthened by workshops at selected science and cryogenic conferences that will include scientists, cryogenic engineers (including the liquid natural gas industry) respectively, as well as NASA project planners to review the Titan Sub concept and add direction and experience to the challenges it faces. The results of all the above efforts will feed into a COMPASS current engineering design run to update the current Titan Sub conceptual design to mature the concept. Launch and delivery options will be explored (in Phase I funds were not sufficient to design more than the Sub itself) on how to deliver this long cylindrical submarine with support from Aero-Entry experts at Georgia Tech. Risks of an exposed phased-array antenna to communicate directly back to Earth will also be explored. A second COMPASS run will develop a Titan Sub that would be delivered as part of an orbiter system. The presence of an orbiter would greatly simplify several aspects of the submarine design, especially delivery and communications.

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **2**



Technology Areas

Primary:

- TX04 Robotic Systems
  - TX04.2 Mobility
    - TX04.2.1 Below-Surface Mobility

Target Destination

Others Inside the Solar System

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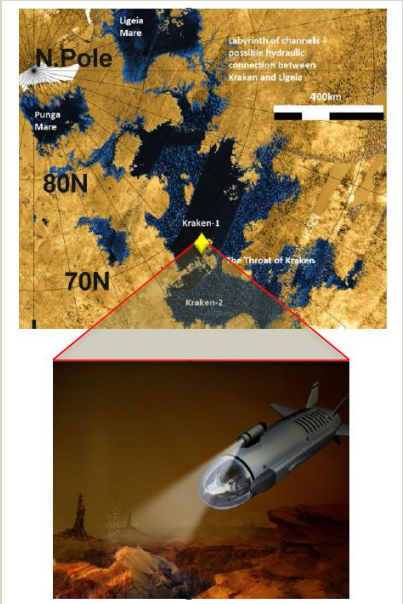
Images



Titan Submarine Concept
Concept graphic of project
(https://techport.nasa.gov/image/102147)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html